Status and Extensions of the NCAR Aerosol Assimilation for CERES

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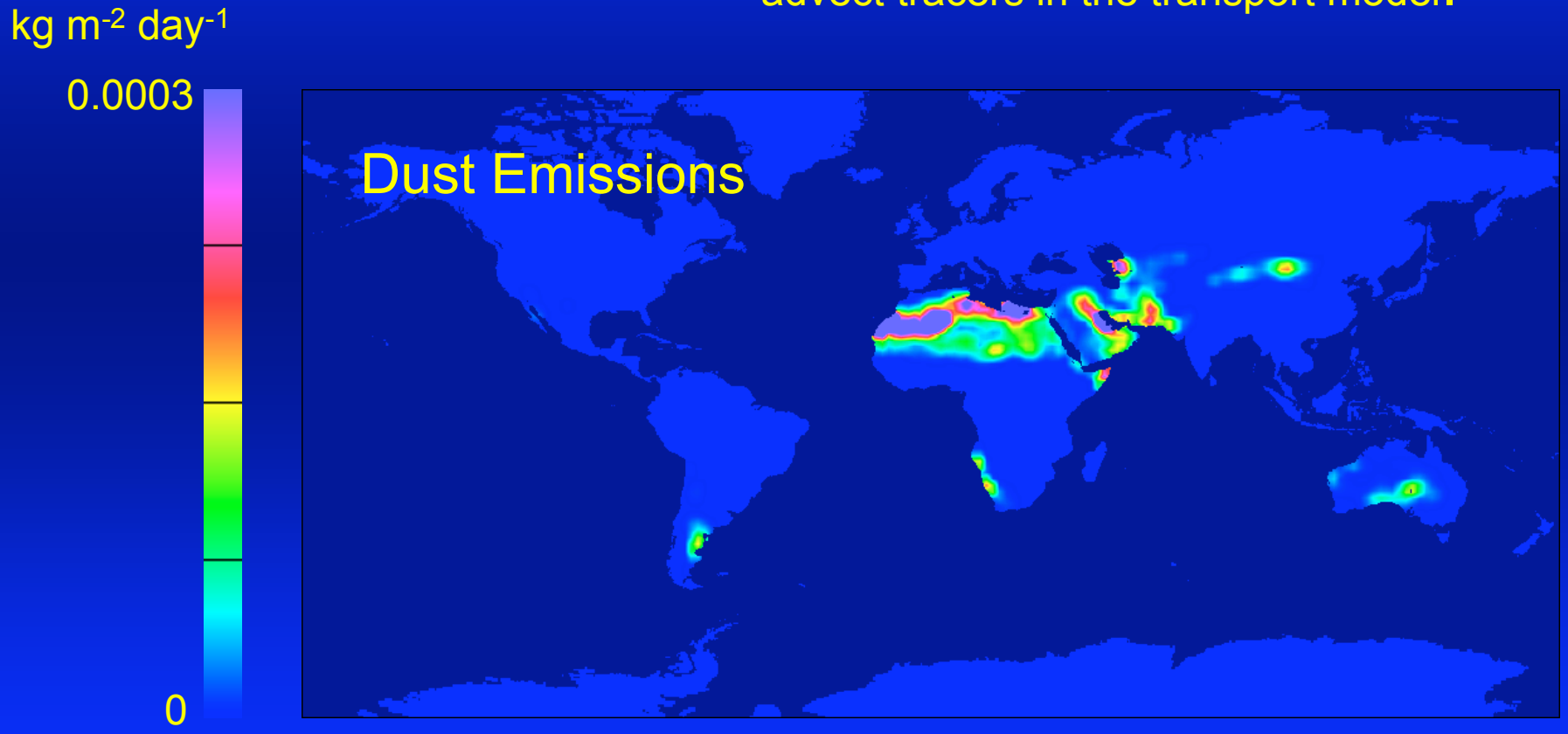
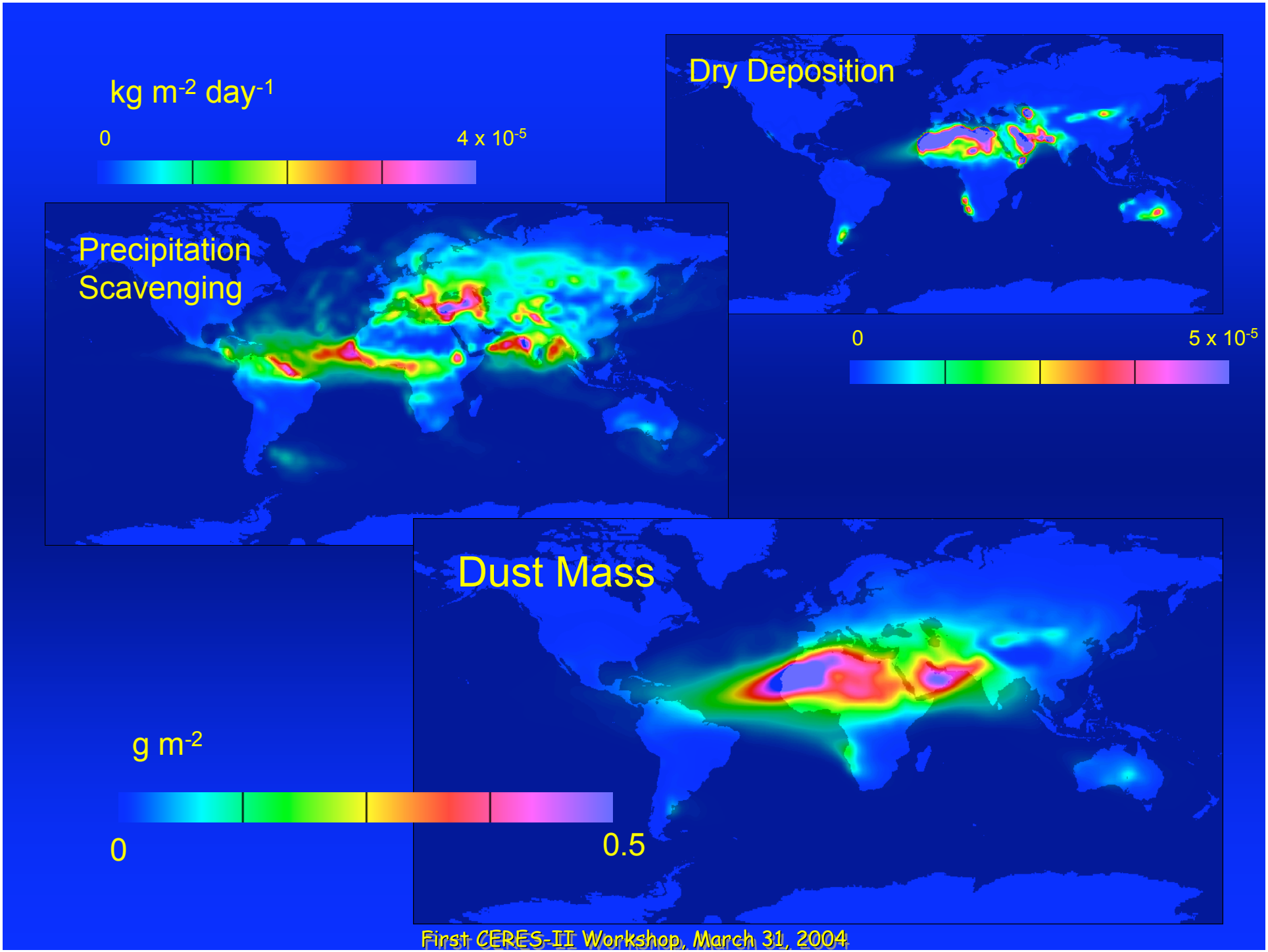
- Model and methodology
- Mass budgets for major species
- Radiative forcing from the assimilation
- Initial error analysis from AEROCOM

Chemical Transport Models

Dust Aerosol Example

Winds from Weather Forecasts/Analyses advect tracers in the transport model.




kg m-2 day-1
0
4 x 10-5
Dry Deposition
0
5 x 10-5
Precipitation
Scavenging
Dust Mass
g m-2
0
0.5

AOD Assimilation
AVHRR Advanced Very High Resolution Radiometer
OR
MODIS Moderate Resolution Imaging Spectrometer

AOD
l = 630 nm
OR 550 nm
Optimal Interpolation

1° by 1° gridded aerosol product
Stowe et al 1997
Kaufman et al 1998

Meteorological fields
NCEP/NCAR Reanalysis
resolution T62 ~ 1.9°, 28 levels
OR **NCEP Aviation Analysis**
resolution T126, 42 levels
OR **CAM** (NCAR Community Atmosphere Model)
resolution T42, 28 levels

MATCH
Model for Atmospheric Transport and Chemistry
Rasch et al 1997

SO_2/DMS/Carbon Aerosol Emission Inventories
monthly climatologies
Benkovitz et al 1996
Cooke et al 1999
Liousse et al 1996

MATCH Configuration

Sulfur Cycle/ Sulfate Aerosol
Gas phase/aqueous chemistry
Barth et al 2000
tracers DMS, SO_2, SO_4, H_2O_2
monthly climatologies for O_3, OH, HO_2, NO_3
from MOZART (Model for Ozone and its Precursors in the Troposphere)

Dust Aerosol
Mobilization and deposition
Zender et al 2003
Mahowald et al 2003
4 size categories
0.005 – 0.5 mm (radius), 0.5 – 1.25 mm
1.25 – 2.5 mm, 2.5 – 5.0 mm

Diagnosed sea-salt aerosol
Blanchard and Woodcock 1980
No nitrate aerosol

Carbon Aerosol
Black Carbon (Soot)
Organic Carbon hydrophobic ➡ hydrophilic
Cooke and Wilson 1996

Hydrological Cycle
Prognostic cloud water
Rasch and Kristjansson 1997
Vertical convection
Zhang and McFarlane 1995
Precipitation - bulk microphysical
Flatau 1989

Aerosol Optics
Sulfate*, Sea-Salt, Organic Carbon, Soot
Optical Properties of Aerosols and Clouds
Hess et al 1998
Dust
Zender et al 2003
*Currently based on $(NH_4)_2SO_4$

How does AOD assimilation work?

Assimilation adjusts model aerosol mass so that model AOD more closely matches satellite observed AOD.

$$t_l = S_s \, S_k \, [Dp_k / g \quad k_l(RH)] \, q_{sk}$$

Single wavelength assimilation scales aerosol mass mixing ratios independent of vertical level and species

$q_{sk} \Rightarrow a \, q_{sk}$ through *Optimal Interpolation*, with a spatial correlation length of ~ 100 km .

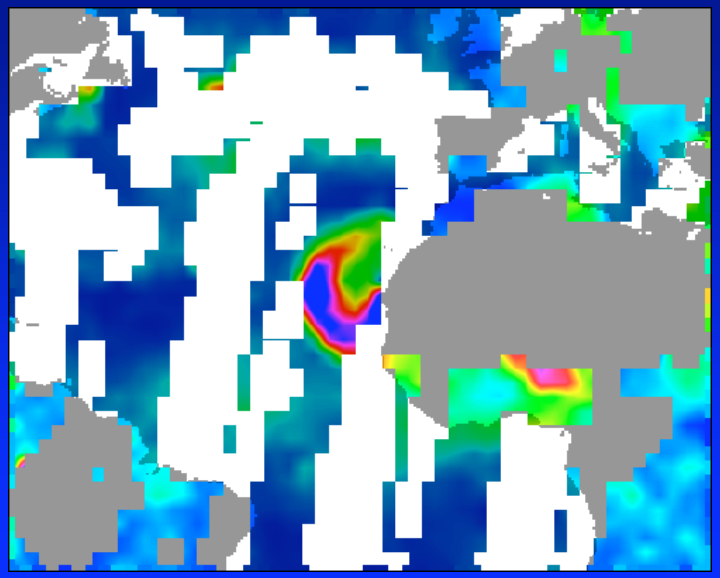
An example illustrates the subsequent model propagation of this mass correction …

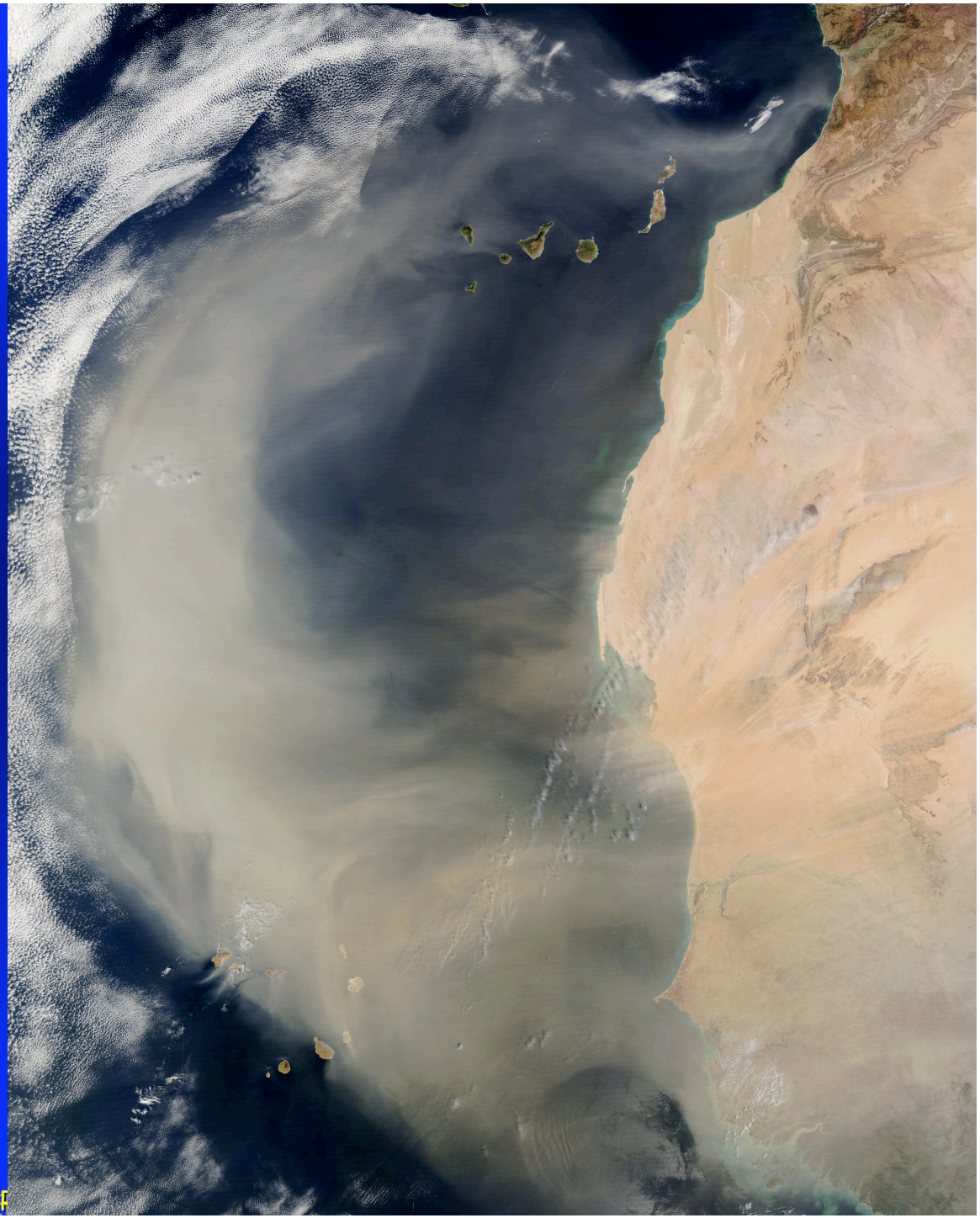
Aerosol Assimilation Example

Saharan Dust Storm March 2, 2003

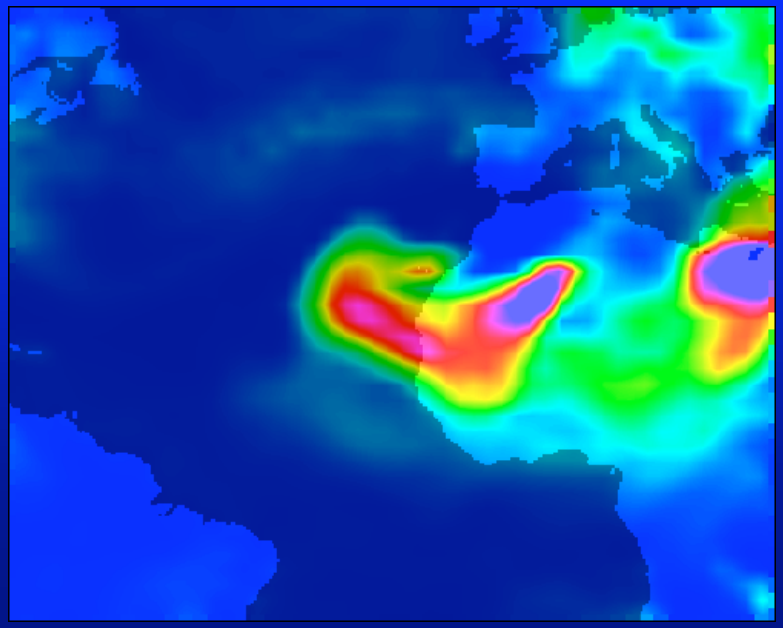
MODIS AOD at
MATCH 1.9° resolution

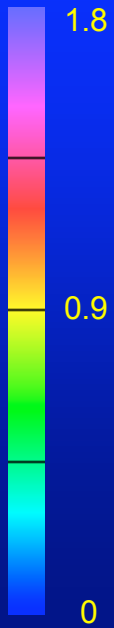
0 0.9 1.8



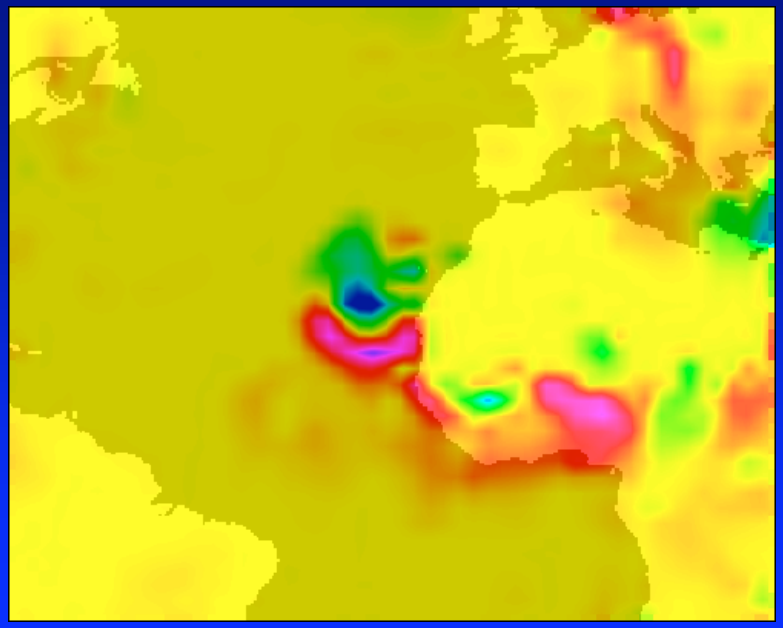


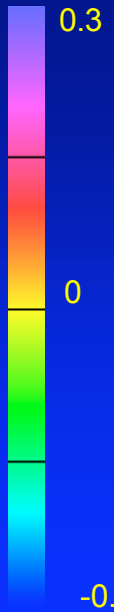
March 2





MATCH AOD





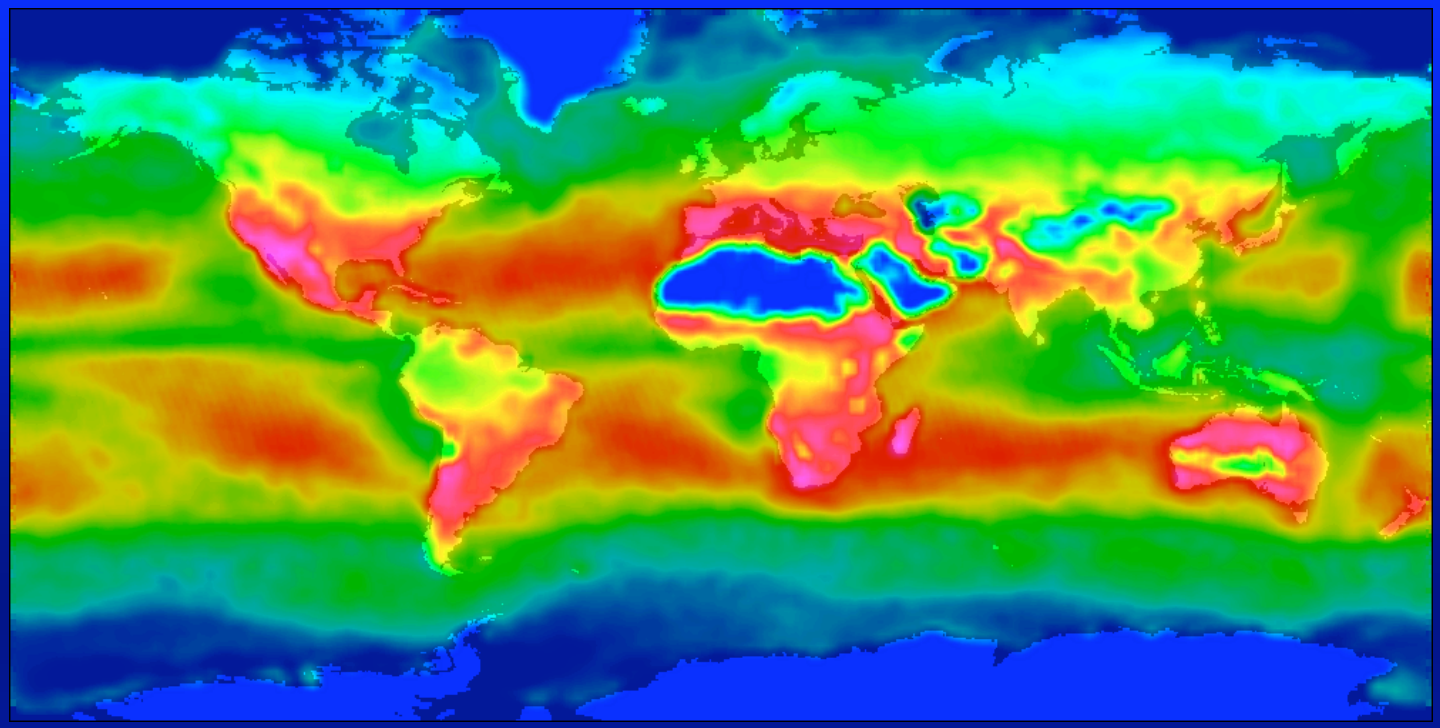
AOD Difference

MATCH with
MODIS Assimilation
(on March 2 only)

-

MATCH

MODIS Sampling 2001



1.0

0.5

0

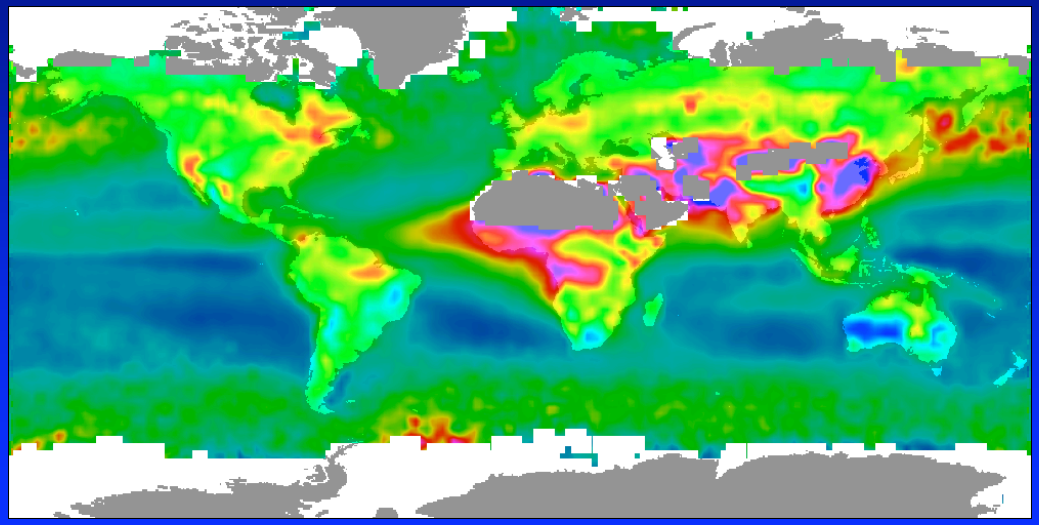
fraction of days with MODIS AOD measurement

MODIS AOD 2001

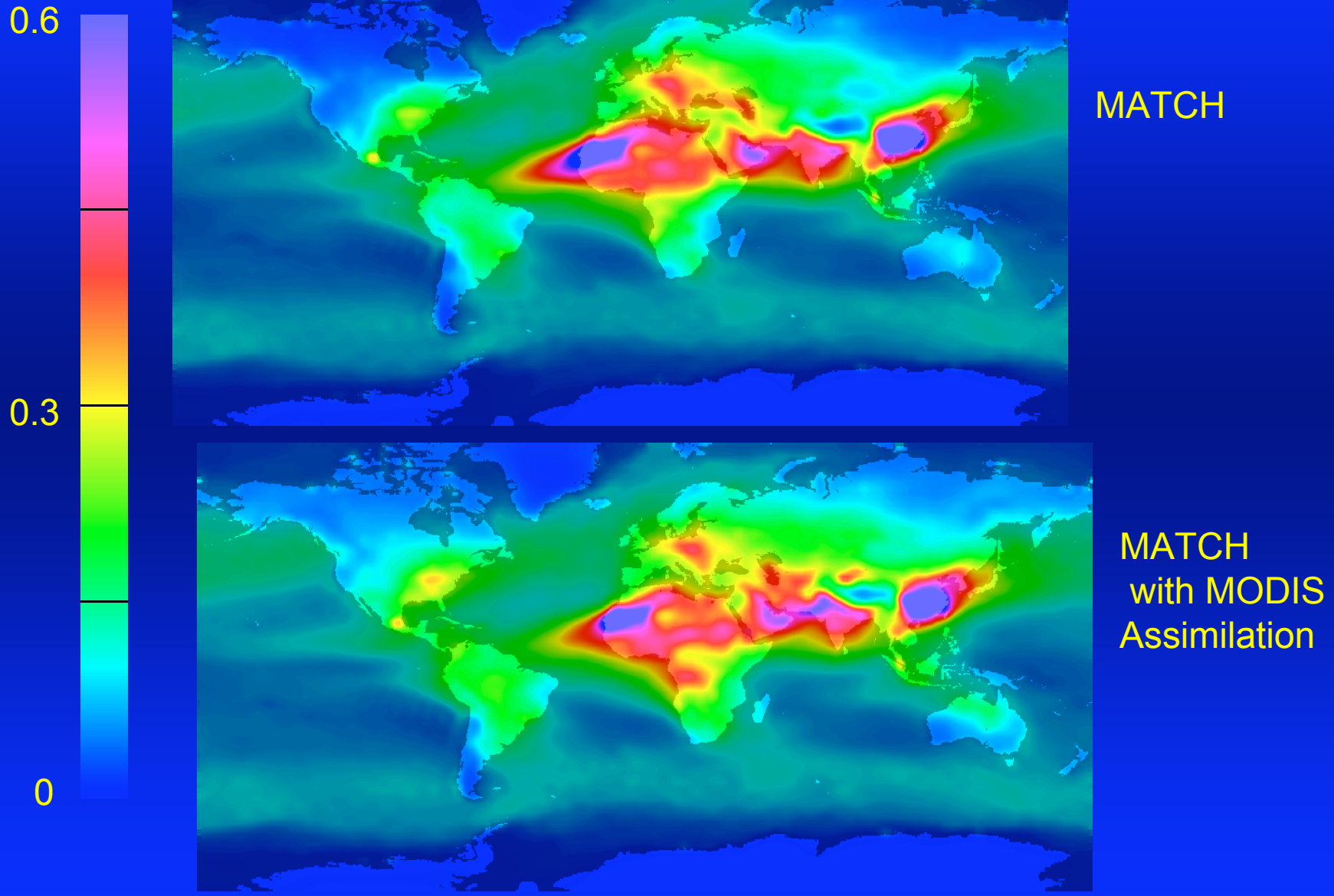
0.6

0.3

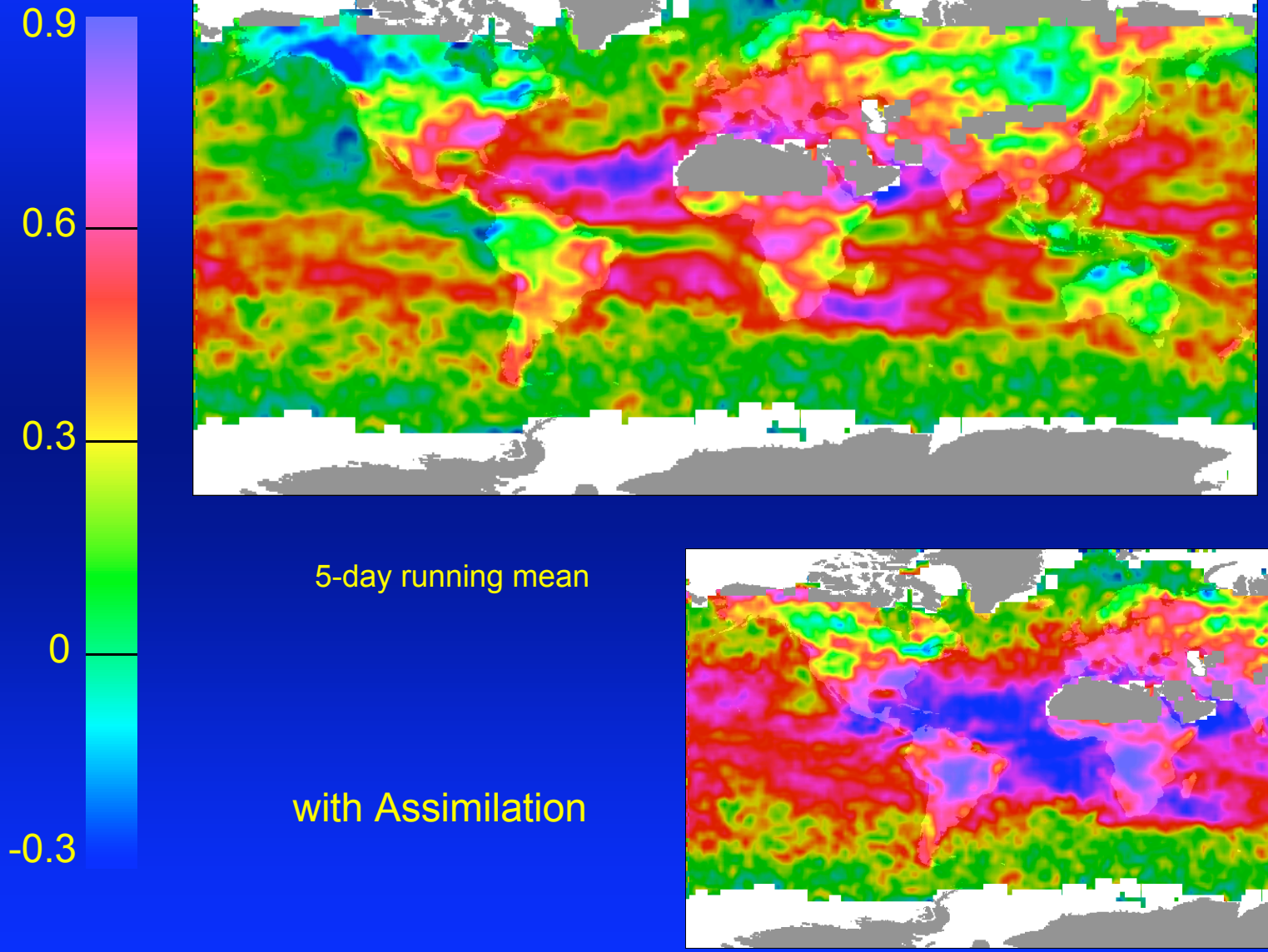
0



Aerosol Optical Depth 2001



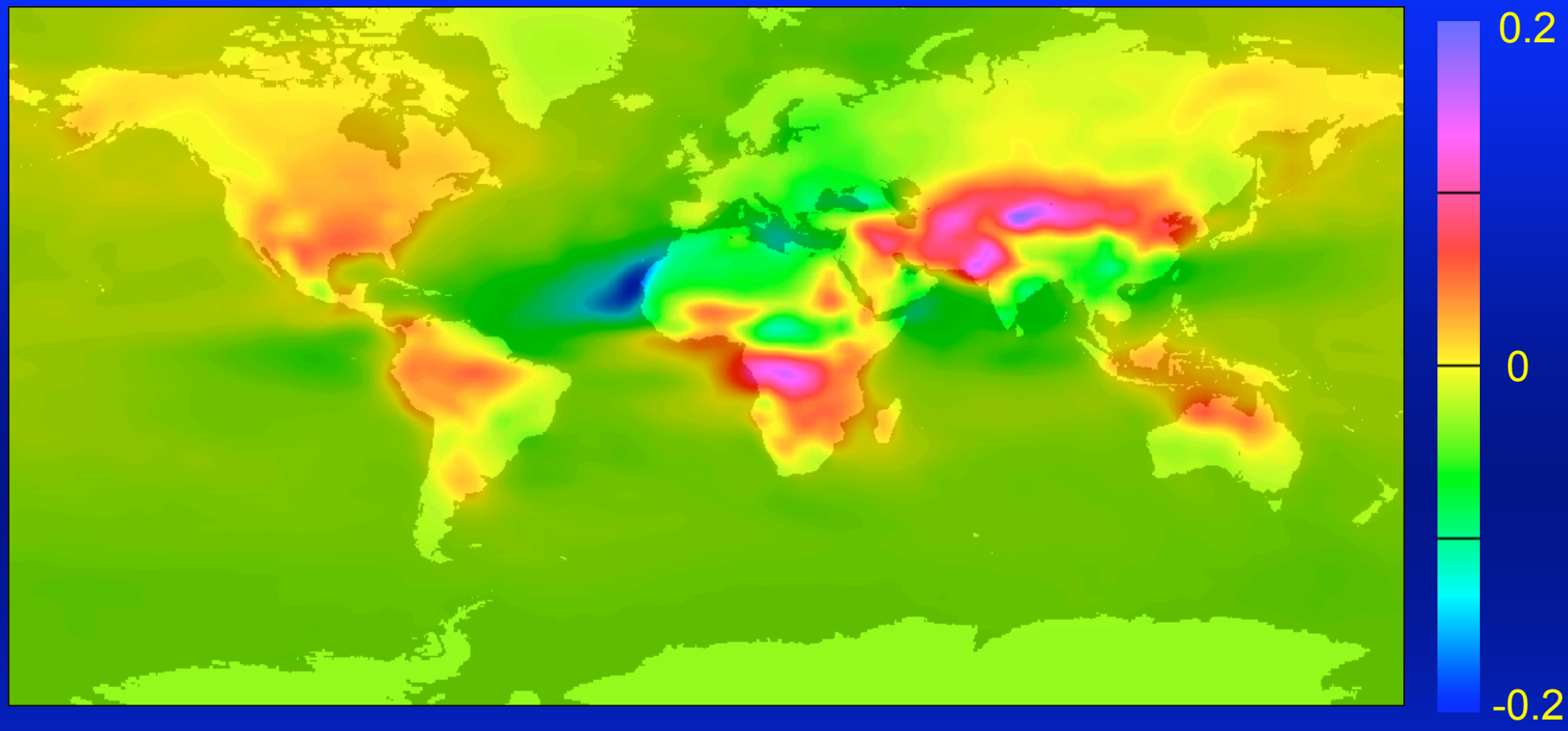
Aerosol Optical Depth MATCH/MODIS Correlation 2001



5-day running mean

with Assimilation

AOD Assimilation Correction 2001



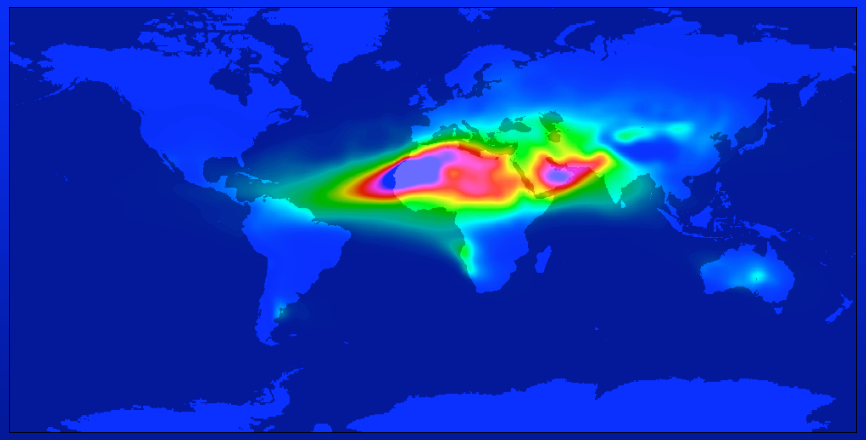
AOD Difference

MATCH with MODIS Assimilation

-

MATCH

Dust Mass Budget

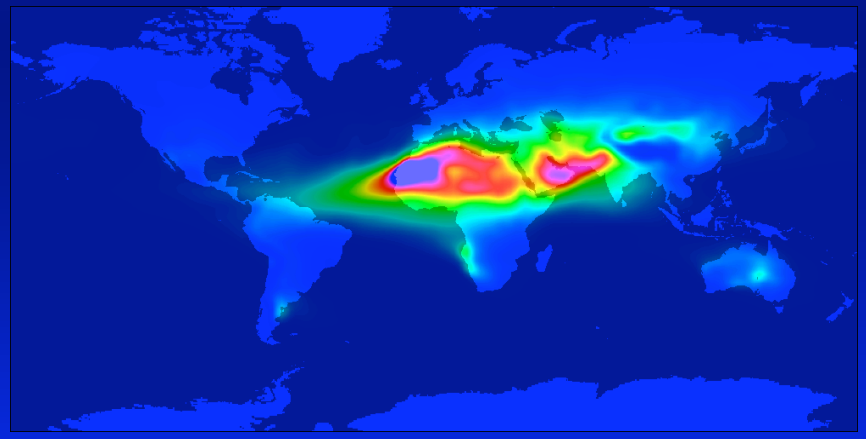


MATCH

Mass ~ 18.6 Tg
Emissions ~ 2.7 Tg day^{-1}
Dry Deposition ~ 1.2 Tg day^{-1}
Wet Deposition ~ 1.5 Tg day^{-1}

t ~ 7.0 days

MATCH with MODIS Assimilation



Mass ~ 16.8 Tg
Emissions ~ 2.7 Tg day^{-1}
Assimilation ~ - 0.3 Tg day^{-1}
Dry Deposition ~ 1.1 Tg day^{-1}
Wet Deposition ~ 1.3 Tg day^{-1}

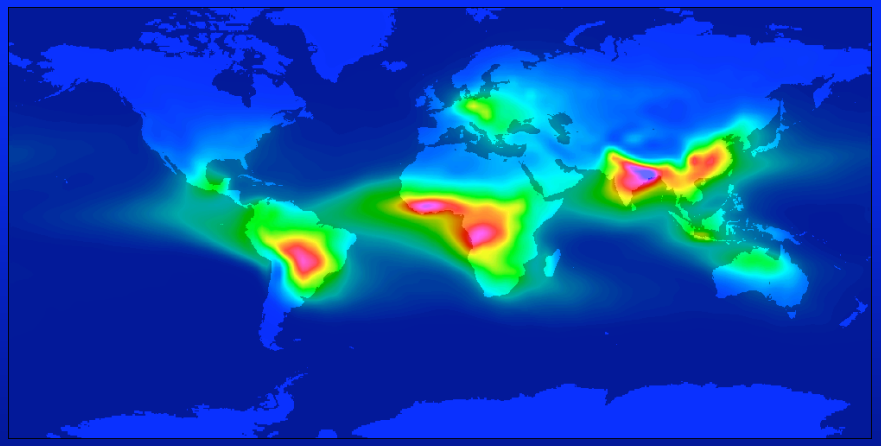
t ~ 7.0 days

Dust Mass

0 0.5

g m^{-2}

Organic Carbon Mass Budget

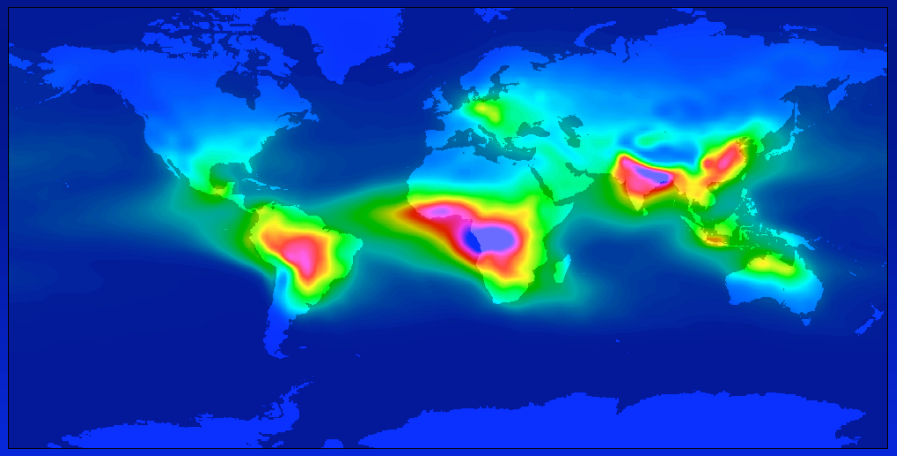


MATCH

Mass ~ 1.7 Tg
Emissions ~ 0.24 Tg day^{-1}
Dry Deposition ~ 0.06 Tg day^{-1}
Wet Deposition ~ 0.18 Tg day^{-1}

t ~ 7.2 days

MATCH with MODIS Assimilation



Mass ~ 2.2 Tg
Emissions ~ 0.24 Tg day^{-1}
Assimilation ~ 0.04 Tg day^{-1}
Dry Deposition ~ 0.06 Tg day^{-1}
Wet Deposition ~ 0.22 Tg day^{-1}

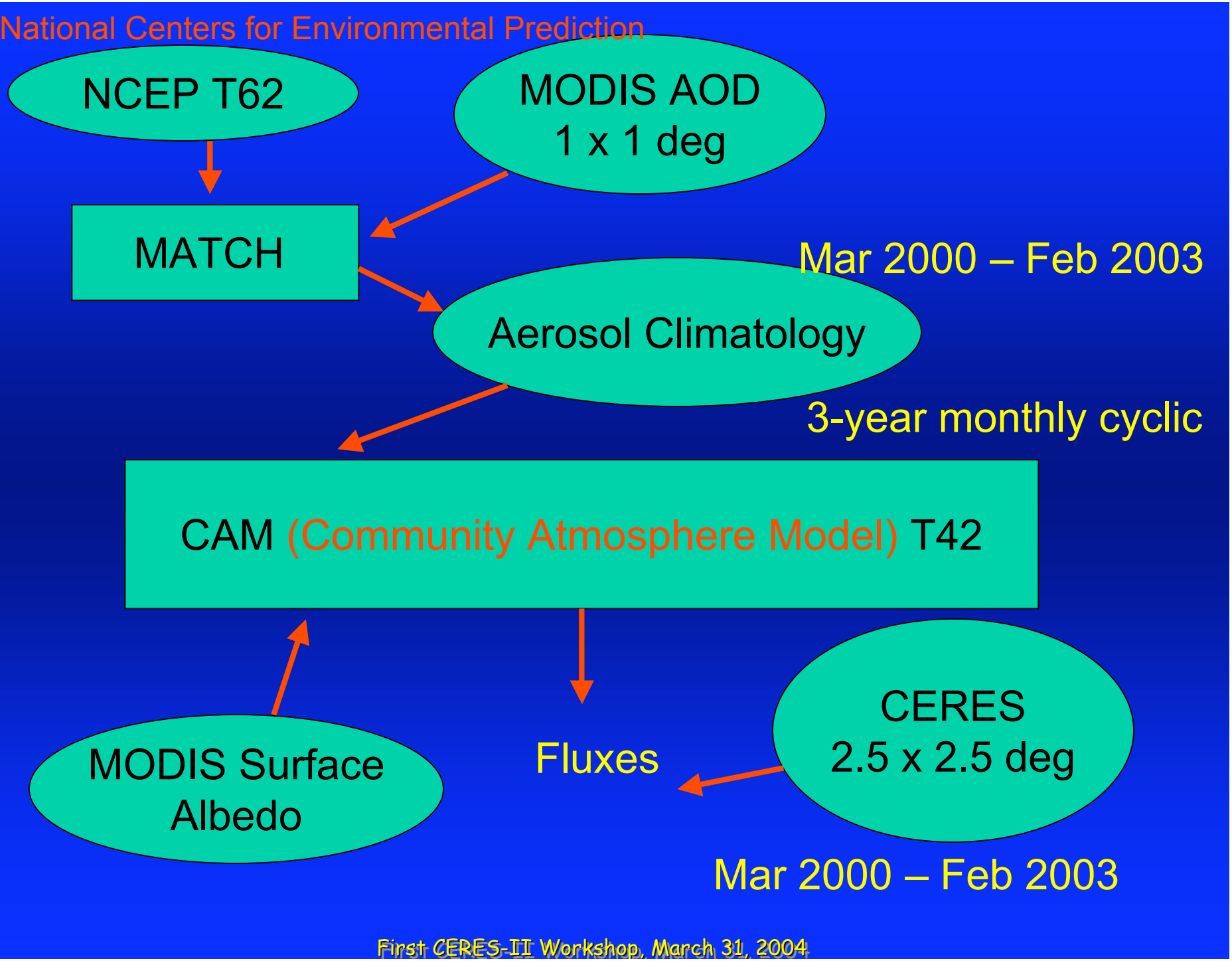
t ~ 7.6 days

Organic Carbon Mass

0 0.03

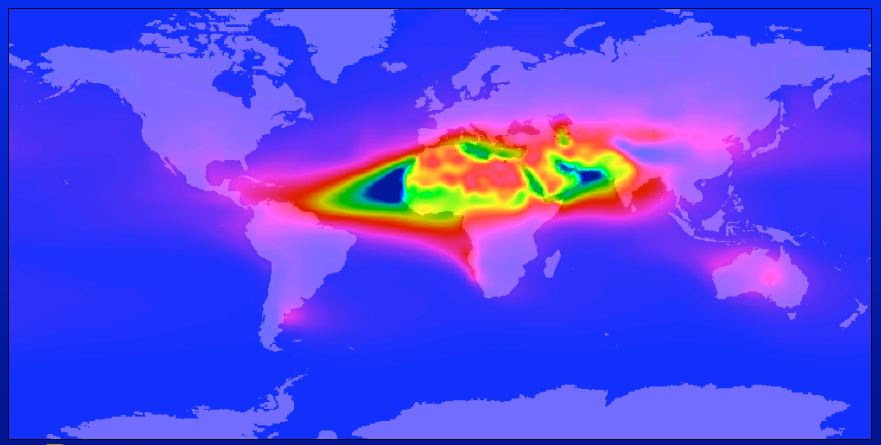
g m^{-2}

National Centers for Environmental Prediction

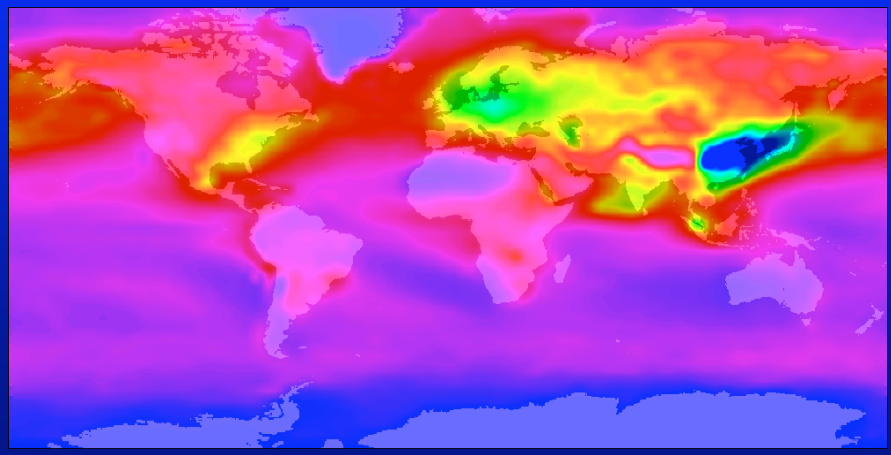


Aerosol TOA SW Radiative Forcing (Clear-Sky)

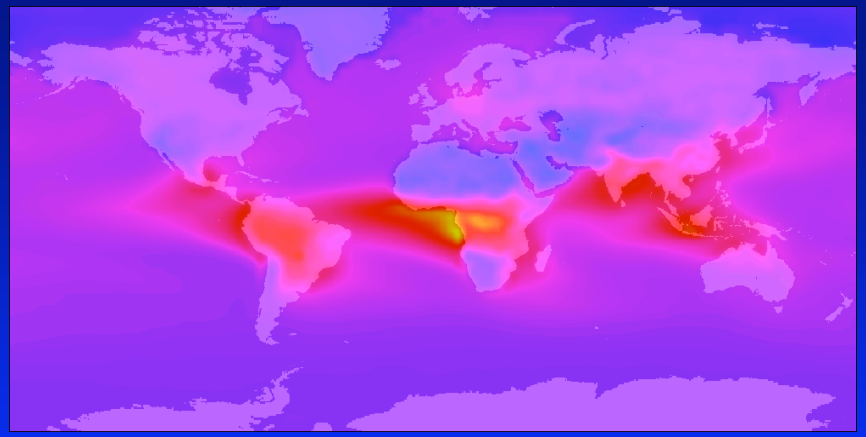
from CAM with MATCH/MODIS Aerosol Climatology



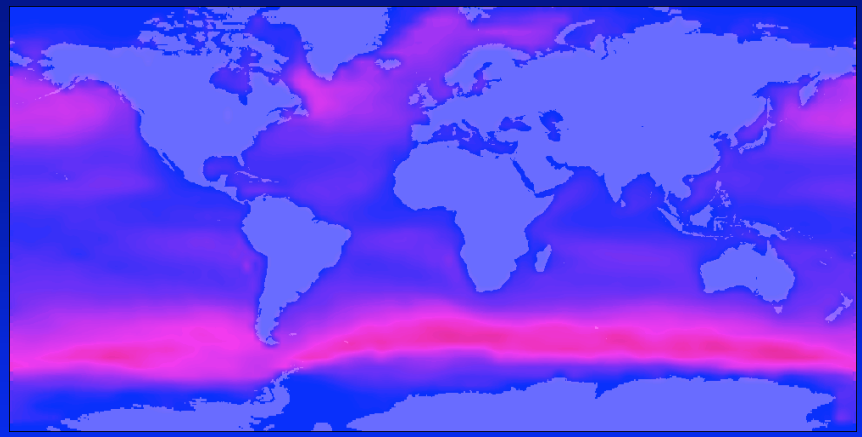
Dust



Sulfate



Carbon

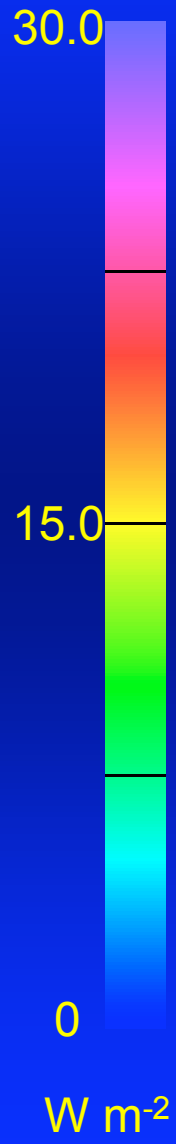


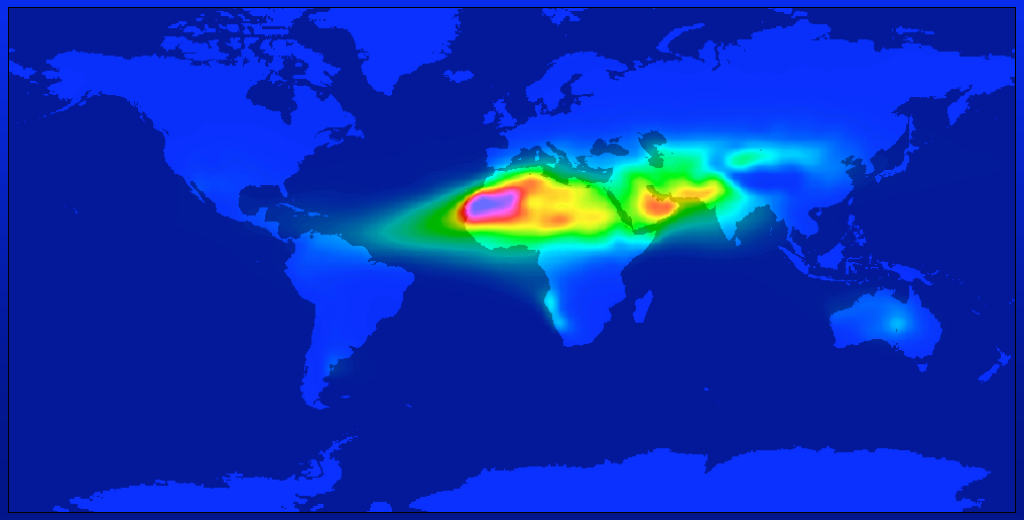
Sea-Salt

W m^{-2}

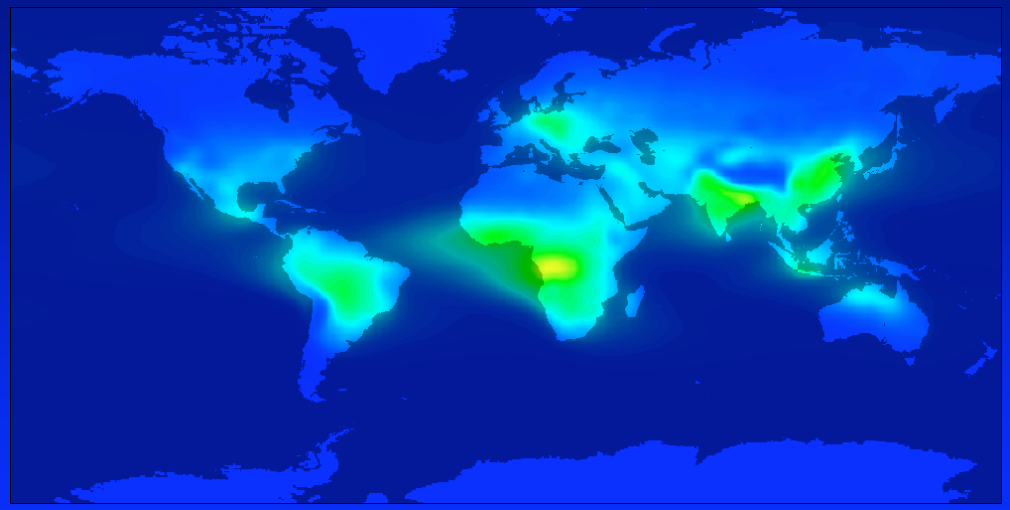
-10.0 0

Aerosol Atmospheric Absorption



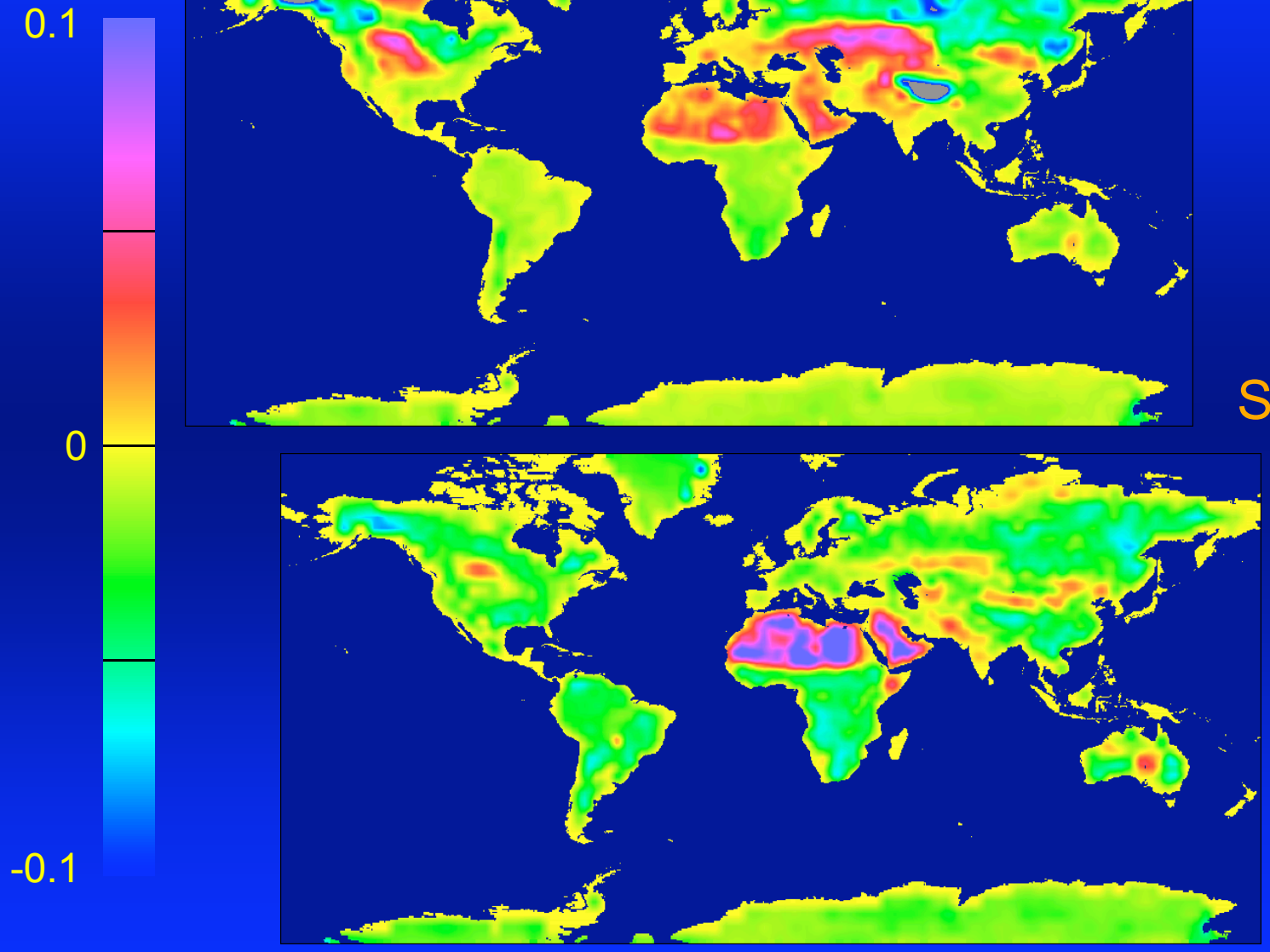


Dust



Carbon Aerosol

Diffuse Land Surface Albedo Differences

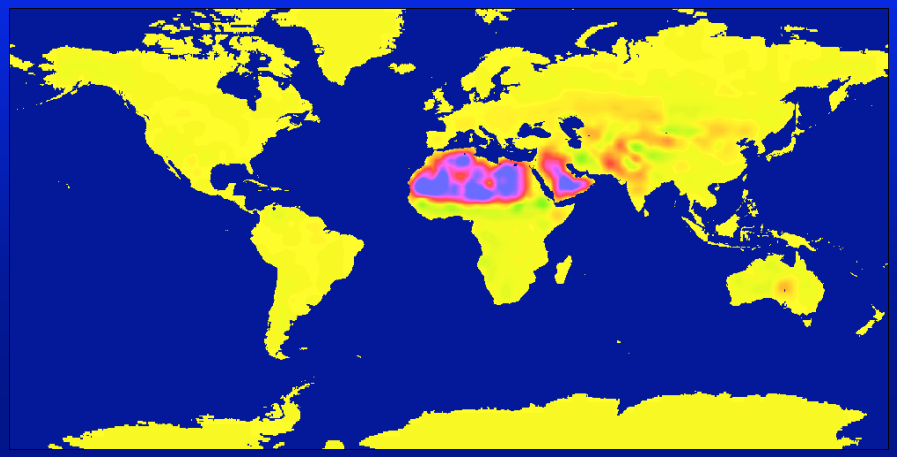


CAM with MODIS Surface Albedo - CAM

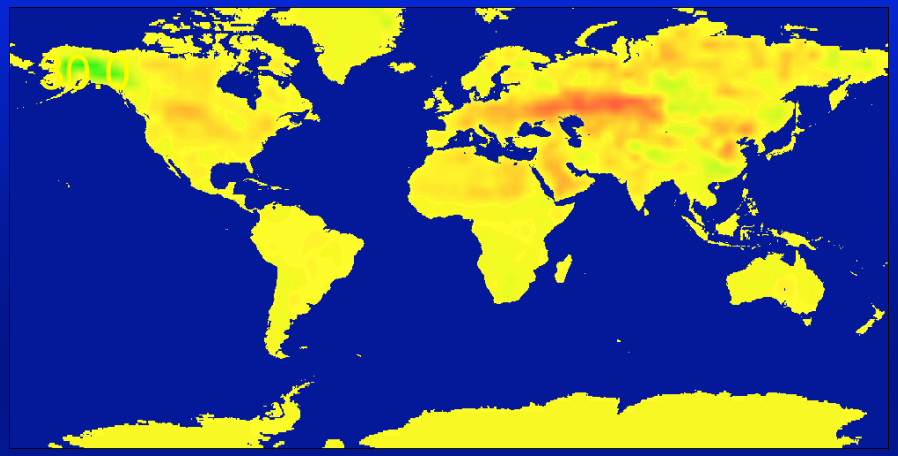
SW

NIR

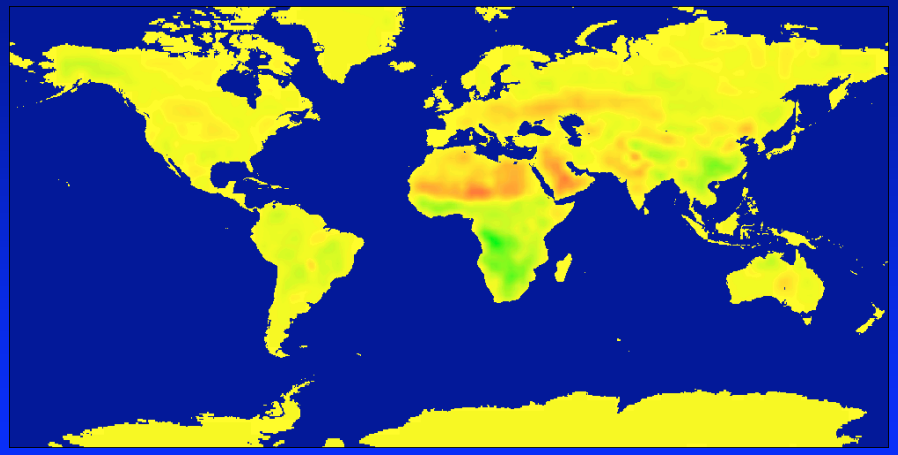
Change in Forcing CAM Surface Albedo ➡ MODIS/CAM Surface Albedo



Dust

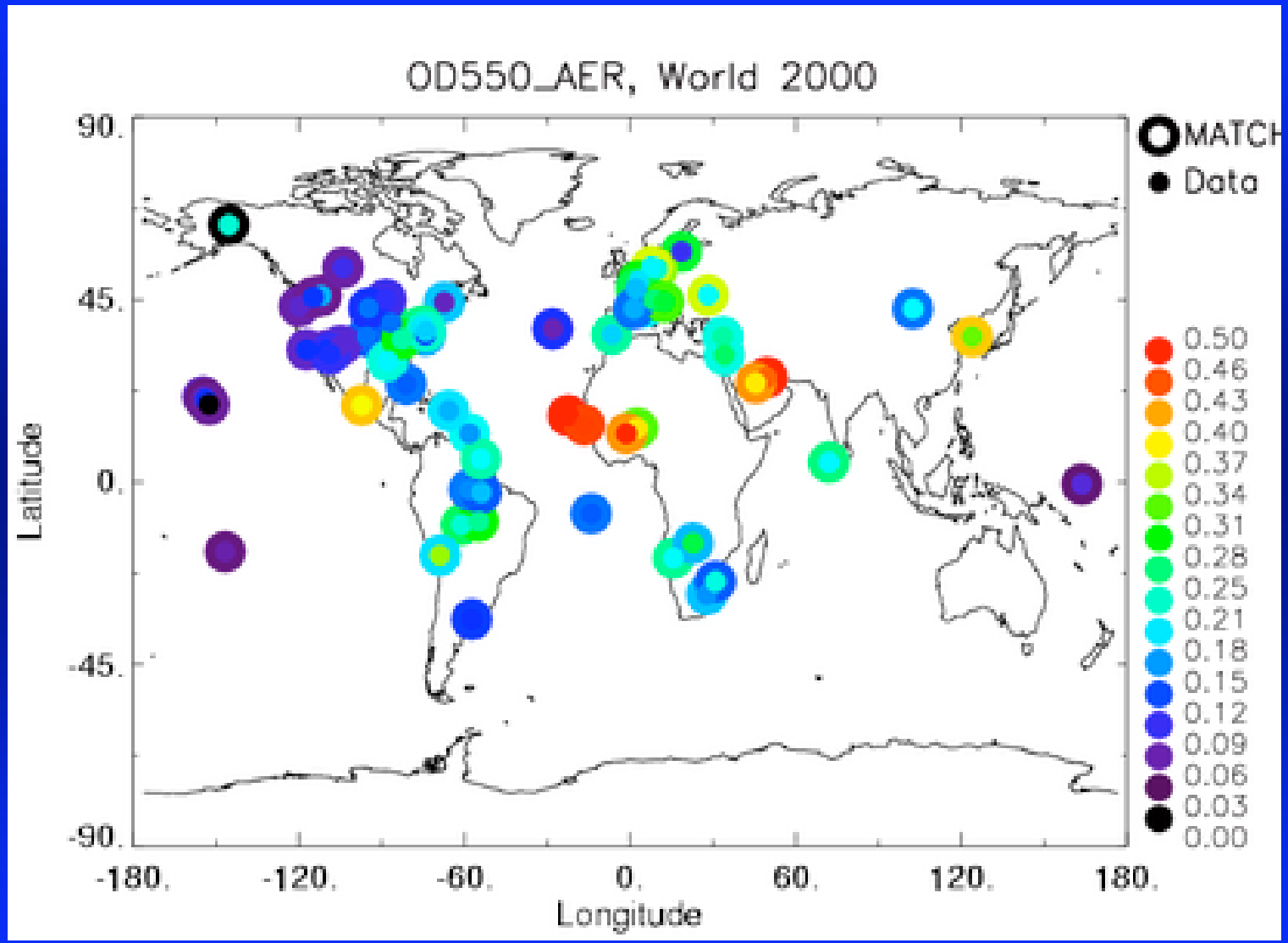


Sulfate

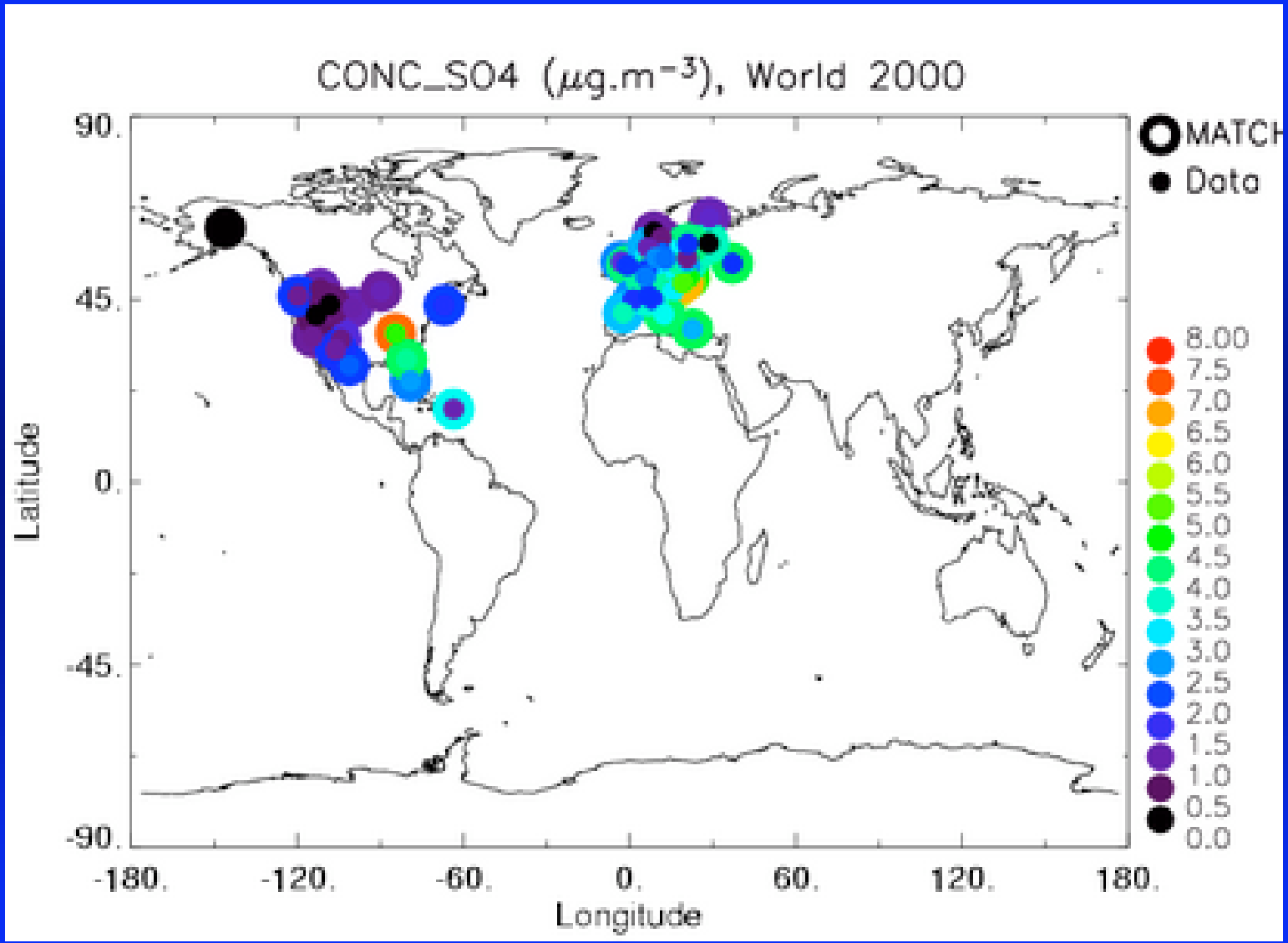


Carbon

Error Analysis from AEROCOM



Error Analysis from AEROCOM



Future Extensions

- Consistent meteorology with SARB
- Investigation of dust optical properties
- New and improved carbon emissions data
- Comprehensive error analysis by AEROCOM

- Better treatment of biomass burning & fires?